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L. G. HANSCOM FIELD, BEDFORD, MASSACHUSETTS

The Short-Backfire Antenna

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OFFICE OF AEROSPACE RESEARCH
United States Air Force

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The Short-Backfire Antenna

Backfire antennas discussed, [1] to [6], are characterized by the multiple reflection of electromagnetic waves between two plane reflectors of different size, with the energy being bound to the longitudinal antenna axis by a slow wave structure. A sketch of a typical backfire antenna is shown in Fig. 1; M marks the larger, R the smaller of the two plane reflectors that are arranged parallel to each other and transverse to the longitudinal antenna axis. The D's indicate a row of dipole elements that constitutes the slow wave structure. The spacing L between the plane reflectors M and R is also the total axial length of the backfire antenna.

The open region between the plane reflectors acts similarly to a laser cavity [5], [6], with a standing-wave field distribution along the axis. The energy is radiated off through the aperture plane VV which passes through reflector R. Optimized conditions, which include optimum adjustment of height and spacing of the dipole elements D as well as of the size of the reflectors M and R, yield a gain increase of 6 dB above an equal-length endfire antenna. For larger backfire antennas an even higher increase in gain is possible if stacked reflectors are used [5], [6].

Until very recently, only backfire antennas that were at least one wavelength long had been investigated. As a result of more recent work, however, an even shorter backfire antenna—in fact, the shortest one at all conceivable (approximately 0.5 λ long)—has awakened an interest all its own. This "short-backfire" antenna is so com-

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pact that practically all of the energy radiated into the cavity is intercepted by reflectors M and R. Over such a short distance, a slow-wave structure would be of no help in trapping the energy, and is therefore not used. The new antenna thus consists of only the plane reflectors M and R, spaced approximately half a wavelength apart, and the feed between them. Although its basic structure is still recognizably that of the backfire antenna, the short-backfire antenna differs so noticeably in design principles and specific constructions described, [1] to [6], as to justify a special name.

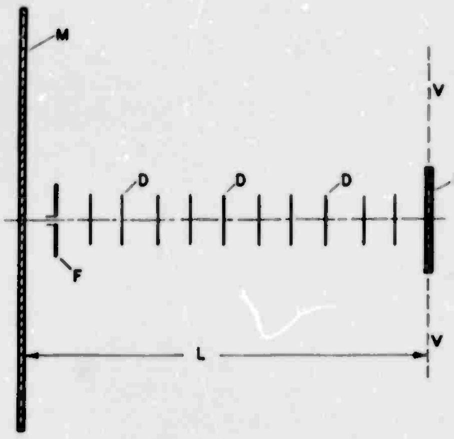

Fig. 1. Backfire antenna structure.

A photograph of an S-band short-backfire antenna model for 3000 MHz ($\lambda = 10.0$ cm) is shown in Fig. 2(a). The diameter of the larger reflector (M) is 2.0 λ; the smaller reflector (R) is a circular metal disk 0.4 λ in diameter, spaced 0.5 λ from the larger reflector. It offers the advantage of being insensitive to the polarization of the feed, which may consequently be linear in any direction, circular or crossed. The width of the rim surrounding reflector M is 0.25 λ. Either reflector could be made from solid or perforated sheet material, or any other structural design equivalent in reflectivity.

The configuration of the short-backfire seems to be somewhat similar to that of the "reflex" antenna developed by G. v. Trentini [7]. However, the two antennas are based on quite different principles and also differ essentially in structure. The reflex antenna applies multiple reflection between a total reflector and a partial one of equal area that usually consists of a number of parallel metal rods or strips, the radiating aperture being defined by the structure and reflectivity of the partial reflector. In contrast the two reflectors of the short-backfire antenna (M and R) differ radically in area (area ratio between 15-to-1 and 30-to-1), with the smaller reflector (R) in its simplest form consisting of a solid metal disk; the radiating aperture forms in the area surrounding the smaller reflector and extends—undisturbed by metal rods or strips—even beyond the cross-sectional area of the larger reflector, as an experimental nearfield study has shown.

The gain of the short-backfire antenna of Fig. 2(a) was measured to be 13.1 dB above a dipole, or 15.2 dB above isotropic at 3000 MHz. Its 360° patterns in E and H plane are presented in Fig. 2(b). Rather remarkably, all sidelobes in the patterns are at least 20 dB below the maximum in the E as well as in the H plane, and the backlobe is far below 25 dB, the lowest level that shows in these patterns; further measurements indicated that it is in fact more than 30 dB below the maximum. These "clean" patterns were obtained over a frequency range of 1-to-1.4. Because the relatively high gain of the short-backfire is mainly due to the higher directivity in the H plane, this antenna type is especially suitable for the reception of horizontally polarized fields on or near ground.

The progress achieved with the new antenna structure can best be demonstrated by comparing it with the Yagi as the most frequently used endfire. A conventional Yagi with a gain of 15 dB isotropic has to be about 4.0 λ long, and needs 15 to 20 dipole elements. The patterns of gain-optimized Yagis have relatively high sidelobes, however, especially in their H-plane patterns. To obtain patterns comparable to the low side—and backlobe patterns of the short-backfire, the number of reflectors and the axial length of the Yagi (number of directors) would have to be markedly increased, and the directors would require tapering to lower heights toward the radiating antenna termination. In Fig. 3 the short-backfire antenna (a) and Yagi (b), both constructed to have the same gain and about the same pattern quality, are shown to the same scaling factor so that they can be directly compared in size and material requirements. Although the reflector area of the short-backfire antenna is larger than that of the Yagi, and in addition a second small reflector is needed, the antenna length is less than one-tenth that of

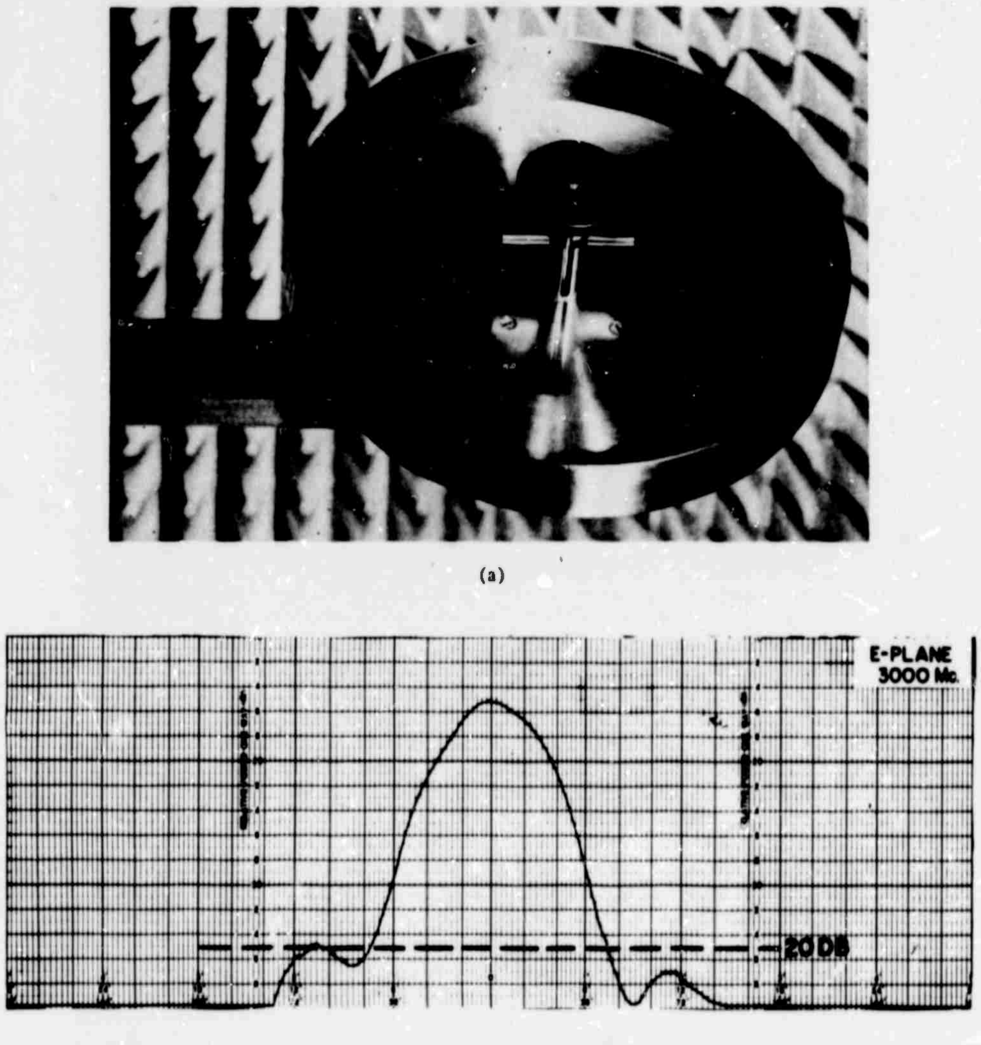

Fig. 2. S-band model of short-backfire antenna. (a) Antenna structure. (b) E- and H-plane pattern for 3000 MHz.

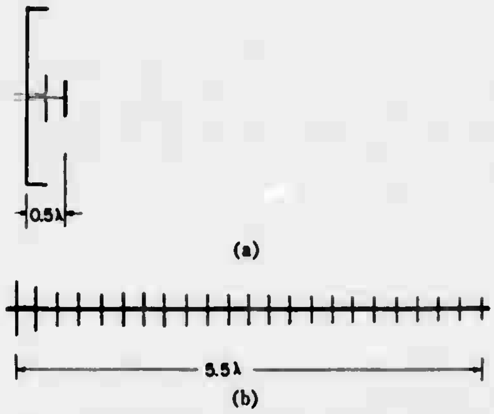

Fig. 3. Comparison of the physical structures of a short-backfire antenna and a Yagi with approximately the same patterns and gain (15 dB above isotropic). (a) Short-backfire antenna. (b) Yagi antenna.

the Yagi and the number of dipole elements is only 1 in contrast to 27 elements for the Yagi (including 5 reflector dipoles not shown).

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References

[1] H. W. Ehrenspeck, "The Backfire Antenna, a New Type of Directional Line Source," *Proc. IRE (Correspondence)*, vol. 48, pp. 109–110, January 1960.
[2] F. J. Zucker, "Surface and Leaky-Wave Antennas," in *Antenna Engineering Handbook*, H. Jasik, Ed. New York: McGraw-Hill, 1961, ch. 16.
[3] H. W. Ehrenspeck, "Reflection Antenna Employing Multiple Director Elements and Multiple Reflection of Energy to Effect Increased Gain," U. S. Patent No. 3,122,745, February 1964. (Additional patents applied for.)
[4] J. A. Strom and H. W. Ehrenspeck, "Backfire Antennas for SHF, UHF, and VHF Bands," AFCRL-63-114, AF Cambridge Research Lab., Bedford, Mass., April 1963.
[5] H. W. Ehrenspeck, "The Backfire Antenna: New Results," *Proc. IEEE (Correspondence)*, vol. 53, pp. 639–641, June 1965.
[6] F. J. Zucker, "The Backfire Antenna: A Qualitative Approach to Its Design." To be published shortly.
[7] G. v. Trentini, "Partially Reflecting Sheet Arrays," *IRE Trans. on Antennas and Propagation*, vol. AP-4, pp 666–671, October 1956.

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A new type of antenna, the "Short Backfire," consists of two plane reflectors, spaced approximately half a wavelength apart, and the feed between them. It develops a high gain and its patterns have a very low sidelobe level.

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